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Content and Timing of Feedback in a Web-based Learning Environment: Effects on Learning as a Function of Prior Knowledge

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Abstract

This study investigated the effectiveness of different types of feedback content (elaborate vs. global) and feedback timing (immediate vs. delayed) for learning about genetics in a web-based learning environment as a function of learners' prior knowledge. It was hypothesized that learning outcomes of students with low prior knowledge would be fostered by immediate elaborate feedback, whereas those of students with more prior knowledge would be enhanced by delayed global feedback. Students' perceptions of the feedback they received were explored. Results showed a significant positive effect of global feedback on learning outcomes for higher prior knowledge learners, although those who received elaborate feedback gave a higher appreciation rating. The findings are discussed in terms of implications for the design and delivery of feedback in web-based learning environments.

Keywords: feedback; prior knowledge; web-based learning; genetics

Content and Timing of Feedback in a Web-based Learning Environment: Effects on Learning as a Function of Prior Knowledge

Feedback, that is, external information about performance that can be used to reduce the gap between current and desired performance (cf. Ramaprasad, 1983), has long been recognized as an important instrument for improving learning (Pressey, 1927). Recent technological developments in education have given feedback research a new impulse. Web-based learning environments are considered a great means for enabling flexible, individually adaptive, and self-regulated learning (Jochems, Van Merriënboer, & Koper, 2004). However, as a consequence of self-regulated and time and place independent study activities, the need for feedback in such environments is even higher than in regular classroom settings, especially when the focus lies on learning complex cognitive tasks instead of drill-and-practice of procedures. Providing appropriate feedback in web-based learning environments can not only contribute to learning by allowing students to verify their answers, evaluate their progress, and determine the cause of errors (Johnson & Johnson, 1993), but can also motivate learners to remain involved in the learning tasks, given that they perceive the feedback as helpful (Hoska, 1993). The challenge for educational researchers and designers of web-based learning environments, then, is to determine what constitutes appropriate feedback for individual students at different moments in their learning trajectory. Two factors are important mediators of the effectiveness of feedback for learning: Content and timing (Goodman & Wood, 2004; Kulhavy & Wager, 1993).

Regarding content, it has been argued that feedback that not just allows students to verify the correctness of their answers, but also provides information that will guide them towards obtaining a correct answer on future tasks, is the most effective (Kulhavy & Stock, 1989). Indeed, a lot of studies have shown that more elaborate feedback has the most effect on learning (e.g., Clariana, 1990, Gilman, 1969; Pridemore & Klein, 1995; Morrison, Ross, Gopalakrishnan, & Casey, 1995). However, definitions of "elaborate" tend to differ. In addition, prior knowledge (i.e., the amount of domain knowledge that learners already possess prior to the learning phase; Jonassen & Grabowski, 1993) is recognized as a factor of influence on feedback effectiveness (Hannafin, Hannafin, & Dalton, 1993), and elaborate feedback may not be effective for learners with high prior knowledge. A lot of research has shown that for learning complex cognitive tasks, learners with little or no prior knowledge of the domain benefit more from guided instruction such as studying worked-out examples than from unguided instruction consisting of solving the equivalent problems, because the guided instruction does not overload working memory capacity (see e.g., Carroll, 1994; Cooper & Sweller, 1987; Sweller & Cooper, 1985; Sweller, Van Merriënboer, & Paas, 1998). As a function of increasing domain knowledge, the threat of cognitive overload and hence the need for instructional guidance decreases. Moreover, at this point, lower levels of guidance may also challenge students to actively relate and integrate the information presented in the learning materials into their cognitive schemata. That is, these students will still have to invest a lot of mental effort in learning, but –unlike low prior knowledge students- this effort will contribute to learning because it is directed at processes that are within their reach (cf. Vygotsky's, 1978, concept of zone of proximal development). Consequently, at higher levels of prior knowledge students' learning starts to benefit more from minimally guided or unguided instruction such as problem solving than from guided instruction such as worked examples (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Kalyuga, Chandler, & Sweller, 2001).

Applied to feedback for learning complex cognitive tasks, which can be conceived of as a form of instructional guidance, this effect suggests that students with low prior knowledge would be expected to benefit more from elaborate feedback that provides them with detailed information on how the problem should have been solved and why it should have been solved this way (cf. process-oriented worked examples; Van Gog, Paas, & Van Merriënboer, 2004). In contrast, students with more prior knowledge would be more likely to benefit from global feedback that provides information on the overall approach of the problem without providing the details of each step to be taken, which they are challenged to fill in themselves (cf. a systematic approach to problem solving [SAP]; Van Merriënboer, 1997).

Regarding timing, a distinction is usually made between immediate and delayed feedback. However, “immediate” and “delayed” can be defined differently depending on the type of task offered. Immediate feedback can be defined as feedback provided immediately after each answer or solution step, which is suitable for drill-and-practice tasks and motor learning tasks (cf. Guadagnoli, Dornier, & Tandy, 1996), or immediately after a whole task, which is more desirable with complex cognitive tasks as this will not interrupt the learning process and will allow the learner to evaluate the solution procedure as a whole. Delayed feedback can then be defined as feedback provided after a task (when immediate feedback is defined as given after each answer or solution step) or as feedback provided after a series of tasks (when immediate feedback is defined as given after each whole task). Note though, that given these differences in definitions of immediate feedback and their consequences for definitions of delayed feedback, not only the feedback timing, but also the number of intervening elements (i.e., solution steps or whole tasks) is being varied. Research on motor learning tasks has suggested that immediate feedback is more effective for less experienced learners, whereas delayed feedback is more effective for more experienced learners (Guadagnoli, et al., 1996).

The present study addresses the question of what type of content and timing of feedback is most effective for students with different levels of prior knowledge in learning about the complex cognitive domain of genetics in a web-based learning environment. It is hypothesized that learning outcomes of students with low prior knowledge would be fostered by immediate (after each task) elaborate feedback, whereas those of students with more prior knowledge would be enhanced by delayed (after a few tasks) global feedback.

Students' perceptions of the feedback they receive are explored, because perceptions of different aspects of educational supply (as for example feedback) can be important determinants of learning outcomes (Walberg, Fraser, & Welch, 1986; Slavin, 1995). Especially in web-based learning environments, students have a high degree of freedom in selecting what they study and how long they will continue doing so, and their perception of feedback as meaningful, of high quality, and helpful can be a major influence on these choices (Mory, 2003).

Method

Participants

Participants were students in the fourth and fifth years of secondary education of two Dutch schools; 172 students had been asked to participate, but due to non-attendance on experimental days only 156 students actually participated (74 males, 82 females; age M = 15.80 years, SD = .97). The experiment was scheduled in the curriculum so that lessons had taken place on basic genetics theory, but students had no experience yet with applying the theory to solve the kind of problems presented in the web-based learning environment.

Materials

Web-based learning environment. The introduction, pre-test, study tasks, feedback, post-test, and feedback perception questionnaire were delivered in a web-based learning environment built for this experiment that also logged participants' answers.

Introduction. In the introduction, participants received general information about the duration and proceedings of the experimental session, and were instructed to log in by providing some demographic information (i.e., name, age, school, and classroom).

Study tasks. The four study tasks consisted of genetics problems, on monohybrid crossings (simple crossings, X-chromosomal crossings, and family trees). Each task contained 5 questions followed by multiple choice answer options, such as for example: "Colour-blindness is caused by a recessive X-chromosomal allele. Could a man who is *not* colour-blind have a daughter who is colour-blind? Could he have a son who is colour-blind?" or "Study this family tree depicting which males and females in this family do and do not have the hereditary disease 'agammaglobulinaemia'. Determine whether the gene that causes this disease is X-chromosomal or not".

Feedback. Feedback was delivered after the study tasks. Global feedback contained only a statement of which answers were correct and a systematic approach to problem solving (SAP; see Van Merriënboer, 1997) used to obtain those answers (i.e., steps to take in problem solving were mentioned). Elaborate feedback not only contained the right answers and SAP, but also fully worked-out solution steps (i.e., steps to take in problem solving were not just mentioned, but also worked-out), and explanations were given for *why* the correct answers were correct. Immediate feedback was provided after each study task (i.e., four times), Delayed feedback was given after two tasks (i.e., two times).

Pre-and post-test. The pre-and post-tests consisted of 10 multiple-choice questions on monohybrid crossings (simple crossings, X-chromosomal crossings, and family trees). The maximum score on each test was 10 points, and the web-based learning environment automatically assigned 1 point for correct and 0 points for incorrect answers. Test problem difficulty was judged to be equivalent for the two tests by two teachers (one of each school; judgment independent of each other). The tests contained problems that were comparable to the study tasks on structural features, but differed on surface features (different 'cover stories').

Feedback perception questionnaire. A feedback perception questionnaire was designed for this study, using the feedback perception scales of the Assessment Experience

Questionnaire (Gibbs & Simpson, 2004) as a basis. The questionnaire consisted of 32 seven-point Likert type items (1 = strongly disagree; 7 = strongly agree), divided over 4 scales that proved reliable (Cronbach's alpha): *usage*, consisting of 5 items ($\alpha = .89$), asking students whether they used the feedback they received; *quality*, consisting of 5 items ($\alpha = .71$), asking students for their perceptions of quality of the feedback; *effect*, consisting of 21 items ($\alpha = .92$), asking students to rate their perceptions of the effectiveness of the feedback; and *appreciation*, consisting of 11 items ($\alpha = .90$), asking students to indicate whether they appreciated the feedback.

Design & Procedure

A 2 x 2 factorial design was used with factors "Timing" (Immediate vs. Delayed) and "Content" (Elaborate vs. Global). Participants were randomly assigned to one of the resulting four feedback conditions: Immediate Elaborate feedback (I/E), Immediate Global feedback (I/G), Delayed Elaborate feedback (D/E), and Delayed Global feedback (D/G). Due to the aforementioned non-attendance of some students, however, not every condition actually had 43 students in it: (I/E: $n = 39$; I/G: $n = 43$; D/E: $n = 39$; D/G: $n = 35$).

The study was run in 5 sessions of approximately 2.5 hours, with 28 to 35 participants per session. Participants first read the introduction and logged in to the environment. They then had thirty minutes to complete the pre-test, after which they had one hour to work on the four study tasks, and, depending on their assigned experimental condition, received Global or Elaborate feedback after each task (Immediate) or after two tasks (Delayed). Participants then completed the post-test, for which they again had 30 minutes, and filled out the feedback perception questionnaire (approximately 15 minutes). Participants were allowed to work out their solutions on paper throughout the entire experiment.

Data Analysis

By a median-split on the pre-test scores, students were assigned to the lower prior knowledge group (at or below the median score of 4; $n = 98$) or higher prior knowledge group (above the median; $n = 58$). In each condition, there were approximately equal numbers of students with lower prior knowledge (I/E: $n = 26$; I/G: $n = 25$; D/E: $n = 25$; D/G: $n = 22$) and higher prior knowledge (I/E: $n = 13$; I/G: $n = 18$; D/E: $n = 14$; D/G: $n = 13$).

Results

For all analyses reported here, a significance level of .05 is used. The means and standard deviations of the post-test scores and feedback perception questionnaire ratings per condition, as well as training and test time-on-task and feedback reading times, are provided in Table 1 for the lower prior knowledge learners, and in Table 2 for the higher prior knowledge learners.

Lower Prior Knowledge Learners

Post-test and questionnaire data of three students were lost due to a logging error. 2 x 2 ANOVAs revealed no significant differences between conditions in mean training time-on-task, post-test time-on-task, or *mean* feedback reading times listed in Table 1 (on *total* feedback reading time an effect of Timing was found, $p = .023$, indicating that students in the I/E and I/G conditions spent more time on reading feedback than those in the D/E and D/G conditions, which is not surprising given the difference in the amount of times feedback was received; i.e., 4 vs. 2). A 2 x 2 ANOVA on the post-test scores of the lower prior knowledge learners, revealed no significant main effects of Timing, $F(1, 91) < 1$, *ns*, or Content, $F(1, 91) = < 1$, *ns*, nor an interaction effect, $F(1, 91) = 1.35$, *ns*.

A 2 x 2 MANOVA on the feedback perception scales showed no significant main or interaction effects of Timing and Content on the perception of usage, quality, effect, and appreciation of the received feedback for the lower prior knowledge learners.

Higher Prior Knowledge Learners

Post-test and questionnaire data of two students were lost due to a logging error. 2 x 2

ANOVAs revealed no significant differences between conditions in mean training time-on-task, post-test time-on-task, or *mean* feedback reading times listed in Table 2 (on *total* feedback reading time a marginally significant effect of Timing was found, $p = .053$, indicating that students in the I/E and I/G conditions spent more time on reading feedback than those in the D/E and D/G conditions, which is not surprising given the difference in the amount of times feedback was received; i.e., 4 vs. 2). A 2 x 2 ANOVA on the post-test scores of the higher prior knowledge learners revealed no main effect of Timing, $F(1, 52) < 1$, *ns*, nor an interaction effect, $F(1, 52) = 1.51$, *ns*, but it did show a significant main effect of Content, $F(1, 52) = 6.38$, $MSE = 3.04$, $p < .05$, $\eta_p^2 = .11$. This effect signified that Global feedback ($M = 5.71$, $SD = 1.51$) was more effective than Elaborate feedback ($M = 4.56$, $SD = 1.98$) for the higher prior knowledge students, irrespective of whether it was provided Immediate or Delayed.

A 2 x 2 MANOVA on the feedback perception scales showed a significant effect of Content on appreciation, $F(1, 52) = 4.81$, $MSE = 1.23$, $p < .05$, $\eta_p^2 = .09$, but not on usage, quality, and effect of feedback. This effect signified that the higher prior knowledge students appreciated Elaborate feedback more ($M = 4.23$, $SD = 1.07$) than Global feedback ($M = 3.61$, $SD = 1.12$). No significant main effects of Timing were found, nor any interaction effects.

Discussion

This study investigated the effectiveness of content and timing of feedback for students with different levels of prior knowledge in learning about genetics in a web-based learning environment, and explored students' perceptions of the feedback they received. Our hypothesis that learning outcomes of students with lower prior knowledge would be fostered by immediate elaborate feedback was not confirmed, no significant differences were found between conditions, nor any differences in feedback perception for lower prior knowledge learners. The hypothesis that learning outcomes of students with higher prior knowledge would be enhanced by delayed global feedback was only partially confirmed: A main effect of content was found, indicating that the higher prior knowledge learners benefited from global feedback, and this effect cannot be explained by significant differences in training time-on-task, post-test time-on-task, or feedback reading times between conditions. Regarding perceptions, however, it was found that the higher prior knowledge students who received elaborate feedback gave a higher appreciation rating.

A possible explanation for the lack of effects of feedback timing and content for the lower prior knowledge learners in this study might be that they were not complete novices, but had some prior knowledge (albeit little, i.e., a score of 4 or less out of ten on the pre-test). This assumption could be addressed in a future study by recruiting participants with larger differences in prior knowledge (i.e., with complete novices vs. proficient learners). In addition, it might be interesting to investigate whether general ability plays a role (apart from, interacting with, or adding to, the effects of prior knowledge) in perception and effectiveness of different types of feedback.

The lack of effects of feedback content on time spent on the feedback may surprise some readers, because it seems intuitive to expect reading time to be higher for elaborate feedback, where more information is given. However, this does not have to be the case, because students in the global condition may be challenged to invest time and effort into actively elaborating on the global feedback themselves. That is, they may spent an equal amount of time as students in the elaborate feedback conditions, but this time is spent on different processes. This would make sense from the cognitive load perspective and in light of the results: Whereas the time and effort invested in elaborating on global feedback will not help low prior knowledge learners (because the lack the required knowledge and cognitive schemata for elaborating or integrating the presented information), it may help higher prior knowledge learners because their prior knowledge enables them to effectively elaborate.

The finding that the higher prior knowledge learners in this study benefited more from global feedback, but appreciated elaborate feedback more, may have interesting implications for the design and delivery of feedback in web-based learning environments. Trying to tailor feedback to learners' needs by offering different feedback types for learners to choose from would be the most easy, but probably ineffective way. Students are likely to select what they appreciate, which may not always be the most beneficial for their learning outcomes.

In addition, in non-experimental settings, learners are required to study in the web-based learning environment for longer periods of time. This implies that not only their prior knowledge is an important factor for the effectiveness of feedback, but that the knowledge they will acquire during this period will also start to play a role. Therefore, after establishing the relationship between levels of prior knowledge and effectiveness of feedback in more detail, a promising direction for future research would be to extend the promising work on dynamic task selection (Corbalan, Kester, & Van Merriënboer, 2006; Kalyuga & Sweller, 2005; Salden, Paas, Van der Pal, & Van Merriënboer, 2006) to dynamic feedback selection for learning complex cognitive tasks in web-based learning environments (cf. the work on intelligent tutoring systems; e.g., Rosé, Jordan, Ringenberg, Siler, VanLehn, & Weinstein, 2001). Moreover, it would be useful not only to assess and take into account students' level of prior knowledge, but also the structure of this knowledge, which may be assessed prior to the experiment using techniques such as concept mapping (Spector, Christensen, Sioutine, & McCormack, 2001) or verbal reporting (Ericsson & Simon, 1993), or online during the experiment using techniques such as Latent Semantic Analysis (Foltz, Gilliam, Kendall, 2000; Graesser, Wiemer-Hastings, Wiemer-Hastings, Harter, Person, & the TRG, 2000).

Another interesting direction for future studies might be the effects of the types of feedback we provided in less structured domains such as literature, or history. The kind of feedback we provided consisted not only of correct/error statements, but included a systematic approach to problem solving (SAP), and –in the Elaborate conditions- worked-out solution steps, and explanations of *why* the correct answers were correct (cf. process-oriented worked examples; Van Gog et al. 2004). As Van Merriënboer (1997) points out, SAPs can include heuristics, and although application of heuristics does not necessarily lead to a good solution, it does increase the chance. So, in less structured (or more ambiguous) domains as literature and history, such feedback including heuristics may provide the best possible kind of guidance for learners.

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Table 1

Means and Standard Deviations of Lower Prior Knowledge Learners' Post-Test Scores, Ratings on the Feedback Perception Questionnaire Scales, and Time (in Minutes) Spent on Training, Post-Test, and Reading Feedback (Mean of the 2 [Delayed] or 4 [Immediate] Times that Feedback Was Received)

			Feedback Perception Questionnaire								Time-on-Task					
	Post-Test		Verification		Quality		Effect		Appreciation		Training		Post-Test		Feedback	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Immediate/Elaborate	4.80	1.89	4.42	1.41	4.58	.71	4.65	.70	4.40	.89	59.57	19.90	23.26	5.93	2.82	2.71
Immediate/Global	4.92	1.91	4.13	1.39	4.38	.93	4.36	.85	4.12	.85	64.27	18.77	24.10	6.53	2.43	2.15
Delayed/Elaborate	4.96	2.21	3.74	1.19	4.41	.98	4.26	.76	4.08	.87	57.80	23.88	23.30	7.37	3.18	2.23
Delayed/Global	4.10	2.21	3.96	1.39	4.12	1.14	4.26	.81	3.89	.83	54.09	18.02	19.69	8.11	3.34	3.79

Table 2

Means and Standard Deviations of Higher Prior Knowledge Learners' Post-Test Scores, Ratings on the Feedback Perception Questionnaire Scales, and Time (in Minutes) Spent on Training, Post-Test, and Reading Feedback (Mean of the 2 [Delayed] or 4 [Immediate] Times that Feedback Was Received)

			Feedback Perception Questionnaire								Time-on-Task					
	Post-Test		Verification		Quality		Effect		Appreciation		Training		Post-Test		Feedback	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Immediate/Elaborate	4.83	1.70	4.11	1.16	4.02	.93	4.52	.97	4.35	1.22	65.73	12.81	25.28	7.96	3.01	2.49
Immediate/Global	5.44	1.15	3.98	1.34	3.99	1.18	4.06	1.03	3.73	1.11	56.06	22.68	23.32	7.55	3.39	2.71
Delayed/Elaborate	4.31	2.25	3.80	1.44	4.50	.94	4.22	.74	4.14	.97	50.29	22.34	23.98	8.94	2.77	3.59
Delayed/Global	6.08	1.89	3.88	1.69	3.69	1.14	3.71	1.04	3.43	1.16	61.13	13.51	22.47	9.22	4.84	4.72